Tywoniak, Stephane and Rosqvist, Tony and Mardiasmo, Diaswati and Kivits, Robbert A. (2008) Towards an Integrated Perspective on Fleet Asset Management: Engineering and Governance Considerations. In Jinji, Goa and Lee, Jay and Ni, Jun and Ma, Lin and Mathew, Joseph, Eds. *Proceedings 3rd World Congress on Engineering Asset Management and Intelligent Maintenance Systems Conference (WCEAM-IMS 2008): Engineering Asset Management – A Foundation for Sustainable Development*, pages pp. 1553-1567, Beijing, China.

Proceedings of the 3rd World Congress on Engineering Asset Management
and Intelligent Maintenance Systems (WCEAM-IMS 2008)
Beijing, China
27-30 October, 2008

TOWARDS AN INTEGRATED PERSPECTIVE ON FLEET ASSET MANAGEMENT: ENGINEERING AND GOVERNANCE CONSIDERATIONS

Stephane Tywoniak[a], Tony Rosqvist[b], Diaswati Mardiasmo[c], Rob Kivits[d]

[1] Faculty of Business, Queensland University of Technology, 2 George Street, Brisbane, QLD 4000.
s.tywoniak@qut.edu.au

[b] VTT Technical Research of Finland, P.O. Box 1000, 02044 VTT, Finland.

tony.rosqvist@vtt.fi

[c] Faculty of Business, Queensland University of Technology, 2 George Street, Brisbane, QLD 4000.
d.mardiasmo@qut.edu.au

[d] Faculty of Engineering and Policy Analysis, Delft University of Technology, The Netherlands
R.A.Kivits@student.tudelft.nl

The traditional engineering perspective on asset management concentrates on the operational performance the assets. This perspective aims at managing assets through their life-cycle, from technical specification, to acquisition, operation including maintenance, and disposal. However, the engineering perspective often takes for granted organizational-level factors. For example, a focus on performance at the asset level may lead to ignore performance measures at the business unit level.

The governance perspective on asset management usually concentrates on organizational factors, and measures performance in financial terms. In doing so, the governance perspective tends to ignore the engineering considerations required for optimal asset performance.

These two perspectives often take each other for granted. However experience demonstrates that an exclusive focus on one or the other may lead to sub-optimal performance. For example, the two perspectives have different time frames: engineering considers the long term asset life-cycle whereas the organizational time frame is based on a yearly financial calendar.

Asset fleets provide a relevant and important context to investigate the interaction between engineering and governance views on asset management as fleets have distributed system characteristics. In this project we investigate how engineering and governance perspectives can be reconciled and integrated to enable optimal asset and organizational performance in the context of asset fleets.

Keywords: Engineering asset management, fleet management, governance, asset performance

1. INTRODUCTION

Asset-intensive organisations such as utilities, heavy engineering, mining, or transportation rely for their operations on assets that are expensive, extensive and/or complex, and have a major impact on organisational performance over extended periods (Jabiri, Jaafari, Platfoot and Gunaratram 2005; Lin, Gao, Koronios and Chanana 2007). The management of these organisations entails the reconciliation of potentially divergent objectives; generating satisfactory economic performance from the assets and complying with governance rules imposed by their environments (Mardiasmo, Tywoniak, Brown and Burgess 2008). Thus the management of the organisation's physical assets provides an exemplary context of how the two divergent objectives are reconciled.

Asset management is a process recognised in many fields, including engineering, information technology and information management systems, financial services and human resources. Many definitions of asset management exist (Mitchell and Carlson 2001; Wenzler 2005; Wittwer, Bittner and Switzer 2002; Woodhouse 2006a), however there is a broad consensus to recognise asset management as the process or cycle in which assets are "put through" in order to create a product or provide a service at optimum level. As Wittwer et.al (2002) define it, asset management is a set of decision-making tools that enable managers to create a framework for both long and short-term planning. The aim of asset management is to integrate the strategic planning of operations, maintenance and capital investment decision-making. The overarching goal is to increase the efficiency of assets, which comprises enhancing asset productivity, maximizing asset value through the life-cycle, and minimizing the total cost of ownership. This can be achieved by (Cornish and Morton 2001a):

- Understanding business costs and performance drivers
- Determining investments to optimize performance and operational costs
- Managing the delivery of network performance and investment programs
- Monitoring asset conditions
- Devising appropriate maintenance policies

.

The scope of asset management is broad as it encompasses "managing (operating, maintaining, repairing, replacing) physical assets including infrastructure and buildings" (Woodhouse, 2003). This wide scope has led to authors using a range of terms in relation to asset management, including "Enterprise Asset Management" (Kim, Ahronheim, Suzuka and King 2007), "Strategic Asset Management" (Davis 2007) or "Engineering Asset Management" (Andreou and Bontis 2007; Chen and Mohamed 2007). In this paper, we use the term "Engineering Asset Management" to designate the technical perspective on asset management.

VTT Technical Research of Finland refers to Mitchell (2002)and defines asset management as "a comprehensive, fully integrated strategy process and culture directed at gaining greatest lifetime effectiveness, value, profitability, and return from production and manufacturing equipment assets". In this definition, two objectives are emphasized:

(1) Maintaining and improving the profit-making capability of production assets, and

(2) Maintaining and optimising the net asset value (physical assets) in the long run

These fundamental objectives are not necessarily aligned at all times as there may be trade-off between short-term profitability and long-term asset values: high asset utilisation and productivity may entail obsolescence (Alchian and Demsetz 1972; Barney and Hesterly 2006; George, McFarlan and Marco 2006). Also, some asset values in particular for infrastructure assets may be impacted by market and industry factors beyond the control of management. Thus asset management entails a range of managerial trade-offs, and overall performance depends on maintaining an appropriate balance between these two objectives.

In recent years, asset-intensive organisations have been under an increased pressure to improve efficiency, in particular in the public sector (Guggenheim and Stahr 2006; Herder and Verwater-Lukszo 2006). A focus on governance and organisational factors has been a central tennet in the management of public assets. Governance is defined as the set of laws, policies, and procedures that ensure organisations run in the interest of owners and resources are allocated, managed, and redeployed to maximise productivity and value (Alles, Datar and Friedland 2005). Governance assists in determining appropriate management processes, organisational structures, and incentives systems to align managerial behaviour and attitudes with the interests of principals (Jensen and Meckling 1976), and the relevant reporting and disclosures that enable proper transparency and accountability (Dunis and Miao 2006). In this perspective, asset governance can be defined as a subset of organisational governance which specifies the policies and processes to acquire, utilise, maintain, and account for the assets of the organisation (Cornish and Morton 2001b). It follows that asset governance can be viewed as a management approach for assets that takes into account asset ownership and the management of distributed systems in a competitive and deregulated market (Bühner 2000; Considine and Lewis 2003; Gomez 2004; Narracott and Bristow 2001; Schmidt and Brauer 2006). Clear definition and differentiation of roles and responsibilities of the asset owner, asset governor, and service providers for operational and maintenance activities is central to asset governance (Cornish and Morton 2001b).

In this paper, we compare and contrast Engineering Asset Management and Asset Governance. Both perspectives approach the management of assets from valid and pertinent perspectives, but each highlights different aspect of asset management. We believe that these perspectives are not competing, but complementary and that valuable insights can be gained through analysing and integrating best practices from each approach.

The paper is organised as follows: section 2 provides an overview of Engineering Asset Management; section 3 describes the principles of Asset Governance; in section 4, both perspectives are compared, presenting basic metrics and methods for their assessment; section 5 concludes the paper with a discussion of how the perspectives can be integrated, outlining further research opportunities.

2. ENGINEERING ASSET MANAGEMENT

Engineering asset management can be considered from both a temporal and a spatial dimension. Typically, from this perspective, an engineered system is looked at through its whole lifetime e.g. daily maintenance, weekly shutdowns, monthly larger shutdowns, and annual overhauls. These activities are repeated over the (economic) life cycle of the system. It is not a surprise that cost calculations are performed to assess the Life Cycle Cost of alternative systems. Basically LCC covers the following cost types: research & development costs, production & constructions costs, operation & maintenance costs, and retirement & disposal costs (Fabrycky and Blanchard 1991).

An extension to Life Cycle Cost analysis is Life Cycle Profit analysis that also use forecasts on the price level of the products produced over the system's lifetime. In both type of life cycle analyses the result is given in the form of Net Present Value. In the case of a system that produces (public) services, we prefer to use the term *public value* (Moore 1995) instead of profit. Measures of public value could, for example, be the ratio of satisfied/dissatisfied service users, or the proportion of the target population using a public service. The measurement of value is in this case much more complex and entails the application of multiple criteria.

During its lifetime, a system is subjected to internal and external dynamics that change its profitability or perceived value. Figure 1 illustrates the forces that ultimately determine the end point of the useful lifetime of a system (Komonen, Kortelainen and Räikkönen 2006). Engineering asset management focuses on the systems' operational phase rather than the whole life cycle including the commissioning phase of the system (this is in contrast to life cycle cost / profit analysis).

It is important to note the system can be a production plant (e.g. a paper mill), a product (e.g. an elevator) or an infrastructure (e.g. a harbour or a railway station). Each of these systems are there to provide services for customers. Some of these systems can be viewed as members of a population of similar entities - in other words a *fleet.*

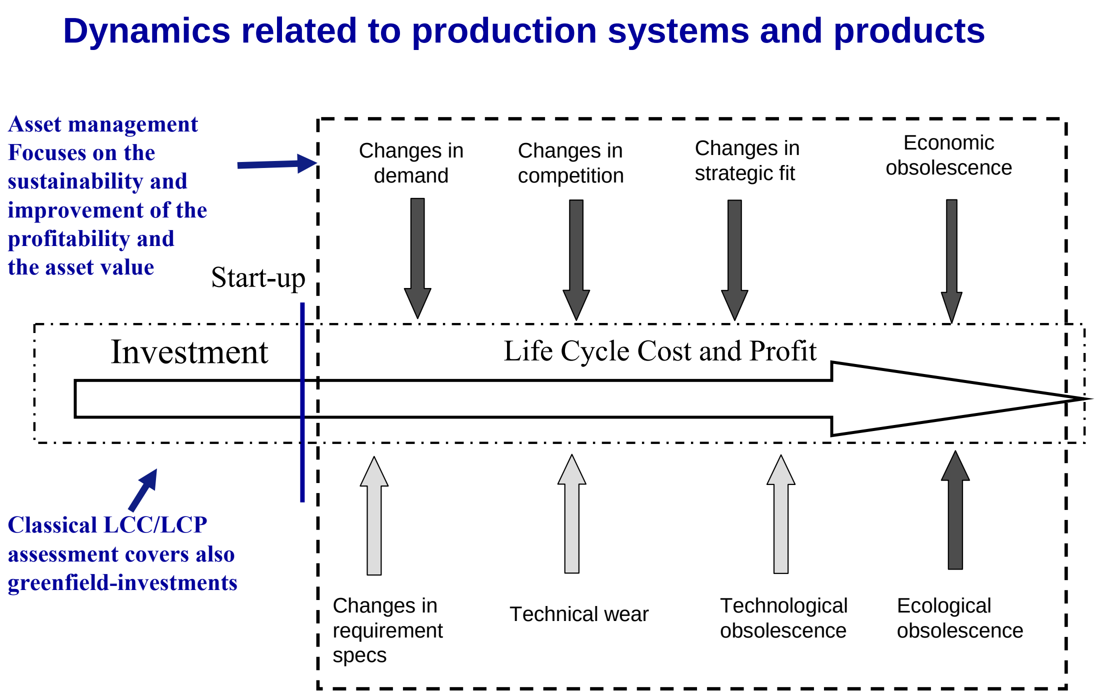

Figure 1. Internal end external dynamics that have to be taken into consideration in asset management

The typical technical perspective to engineering asset management focuses on those dynamics that are shown by the light arrows in Fig. 1. For example; technical wear, requirement specification and technological obsolescence. By performing maintenance and modifications on the system we can alleviate the effects of these dynamics that would otherwise ‘kill’ our system. The major part of the external dynamics are market and business related (the dark arrows in Fig. 1) and not usually controllable by the corporate or business unit managers. In practice, the external dynamics have a much more profound effect on the profitability and value of the physical assets than the technical dynamics (indicated by the light arrows in Fig.1).

If we look at the maintenance processes related to a complex physical asset, we get an idea how demanding operational management can be. Fig. 2 shows a diagram how maintenance can be optimized based on maintenance and operational data. It also shows how investment needs are identified based on this data augmented by business intelligence (ref. to the dark arrows in Fig. 1).

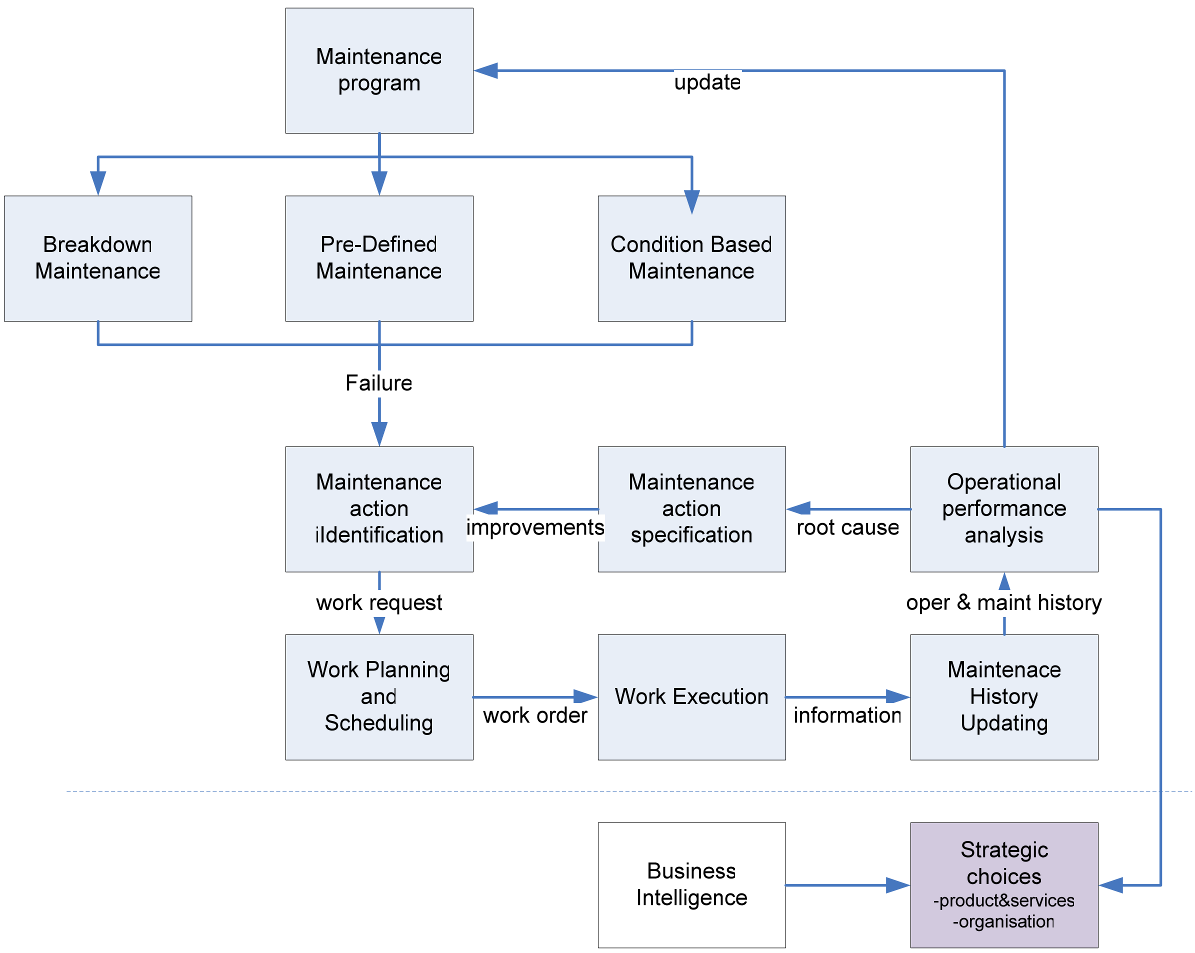

Figure 2. Learning loop related to maintenance to sustain and improve operational performance and asset value

The dashed line in Fig.2 demarcates operative optimization based on learning from experience from the strategic concerns. Details related to Fig. 2 can be found in Rosqvist et al. (2008, in press). It is important to note that based on operational performance and business intelligence asset strategy is updated and strategic choices are made related to, e.g. product mixes and production technology, business processes (e.g. outsourcing/insourcing maintenance work).

The feedback loop is activated by failure reports, work requests, work orders and technical information that have to be processed in order to update the maintenance program properly. In addition, asset fleets with similar entities are usually distributed along the life cycle of the system, demanding managerial attention for different prevailing dynamics relevant for the different groups (see Fig. 1).

Engineering Asset Management has an abundance of *metrics* that have been defined to support managerial decision-making. Every organization has its own collection of metrics that are of strategic significance for the company – the Key Performance Indicators (KPI). KPIs differ between different types of assets. Companies, whether profit-making or non-profit, use and manage different technologies, possess different skills, and provide different services as a function of their role in the service network. Thus the KPIs for a company are always dependent on the context of its business and are based on the strategic analysis of the business environment and the success factors identified.

The Total Productive Maintenance (TPM) framework, a framework for continuous improvement is of particular relevance to Engineering Asset Management. TPM is a structured way to increase plant productivity by a better performance of the equipment lines, step by step, with the aim of creating an optimum co-operation between the production departments and maintenance. It encourages changes in the way things are done at the shop-floor level[1].

The principal metric of TPM is known as the Overall Equipment Effectiveness (OEE). This figure ties the 'six big losses':

1. Equipment failure

2. Setup & Adjustment

3. Small Stopps

4. Reduced speed

5. Startup rejects

6. Production rejects

to three measurables; Availability (Time), Performance (Speed) & Quality (Yield). When the losses from Time * Speed * Quality are multiplied together, the resulting OEE figure shows the *relative* performance of any equipment or product line compared to the ideal (theoretical) performance. Table 1 gives examples of typical losses in manufacturing systems. When we know what the Six Big Losses are and the primary events that contribute to these losses, we can focus on ways to monitor and correct them.

Table 1

The Six Big Losses, and how they relate to the OEE loss categories.

Six Big Loss Category		OEE Loss Category	Event Examples
6.1.1.1.1	Equipment failure	Down Time Loss	• Tooling Failures • Unplanned Maintenance • General Breakdowns • Equipment Failure
6.1.1.1.2	Setup and Adjustments	Down Time Loss	• Setup/Changeover • Material Shortages • Operator Shortages • Major Adjustments • Warm-Up Time
6.1.1.1.3	Small Stops	Speed Loss	• Obstructed Product Flow • Component Jams • Misfeeds

[1] The TPM program closely resembles the popular Total Quality Management (TQM) program. Many of the tools such as employee empowerment, benchmarking, etc. used in TQM are used to implement and optimize TPM. Differences are in the objectives, means and targets: TQM promotes quality whereas TPM reliability of equipment. TQM engages management and is more ‘software-oriented’, TPM engages operational personnel and is more ‘hardware-oriented’. TQM looks at CriticalToQuality – metrics, TPM looks at waste and efficiency metrics.

			• Sensor Blocked • Delivery Blocked • Cleaning/Checking
6.1.1.1.4	Reduced Speed	Speed Loss	• Rough Running • Under Nameplate Capacity • Under Design Capacity • Equipment Wear • Operator Inefficiency
6.1.1.1.5	Startup Rejects	Yield Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • Incorrect Assembly
6.1.1.1.6	Production Rejects	Yield Loss	• Scrap • Rework • In-Process Damage • In-Process Expiration • Incorrect Assembly

Figure 3 shows how the 'TPM-metrics' can be approached by looking at how productive and non-productive activities are distributed along the time axis (SEMI 2000). Given the time definitions in Fig. 3 metrics for computing the OEE are defined as shown in Fig. 4.

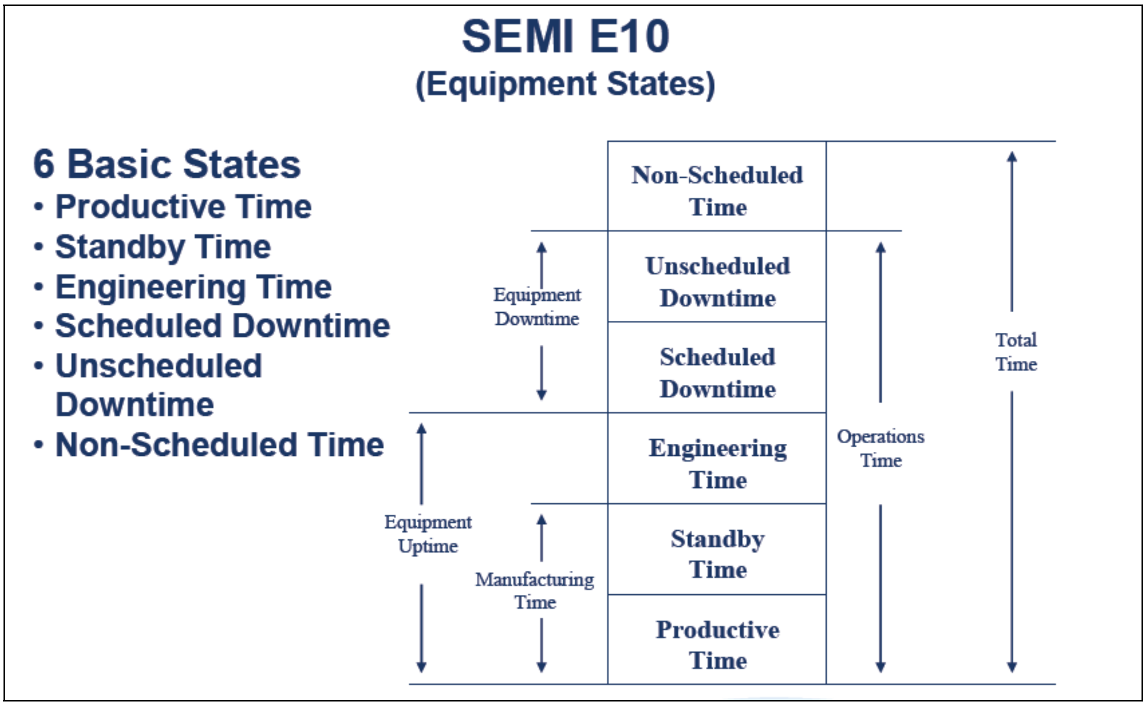

Figure 3. SEMI 10 time definitions and the six basic states of a production system.

Figure 4. SEMI E79 formulas for computing the Overall Equipment Effectiveness (OEE).

The OEE factors in Fig. 4 link to the time definitions of E10 according to the scheme in Fig. 5.

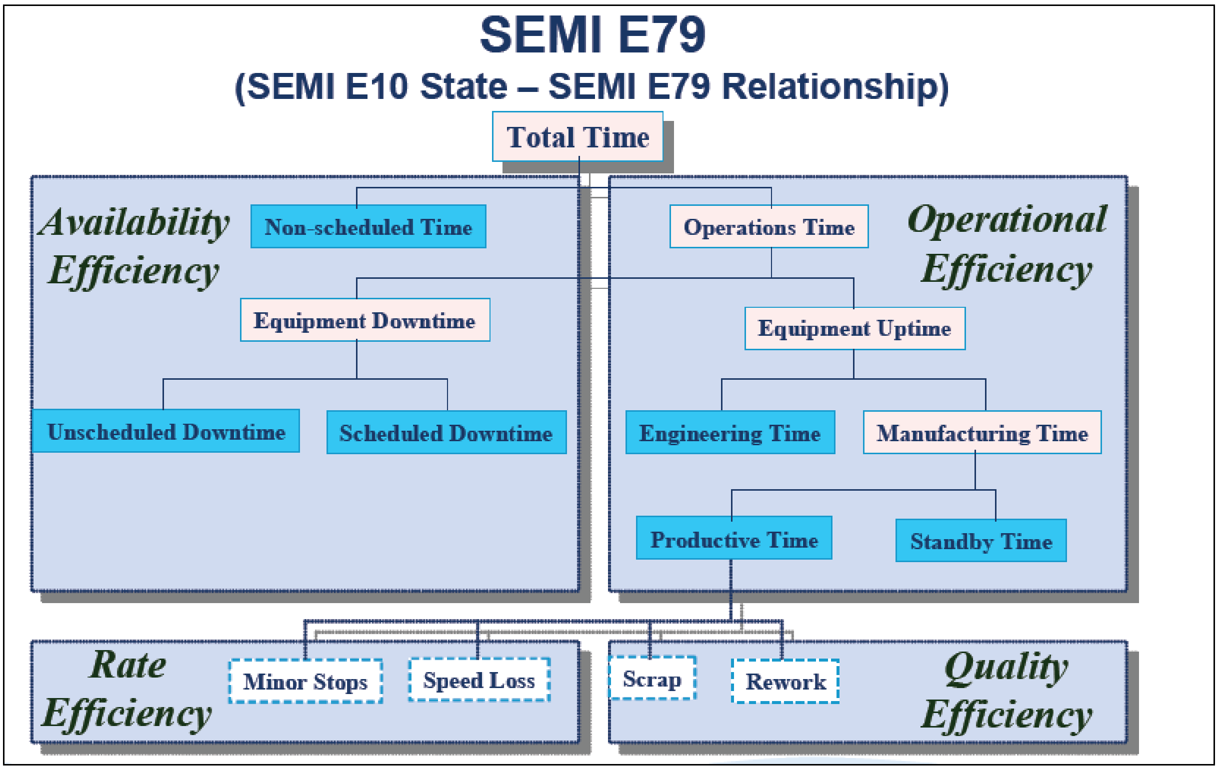

Figure 5. Time variables and their linkage to OEE parameters.

At the shop floor level we can identify several means to improve OEE:

- Advanced process control methods
- Condition – based maintenance
- Preventive maintenance scheduling
- Structural health audits

OEE is *the* measure for the reliability and production design engineers. A comparable metric for a production economist would be for example the Return on Investment (ROI). The metrics of the engineer, and those of the economist, only look at the system performance from a single perspective. This disjunction obviously calls for an integrative approach. However, before we can discuss how the engineering and financial perspectives can be aligned a number of issues need to be reviewed.

First among these is the issue of organization. The engineering view usually takes for granted that there is an organization that provides the infrastructure for skilled people to deliver services (Bhagwat and Sharma 2007). Whilst such an assumption is valid in the case of fully integrated organizations, it does not hold for many XXIst century organizations which have outsourced a range of activities to networks of providers (Sturgeon 2002). This dis-integration of organizations has several management implications: the focus of management is broadened from organizational boundaries to network boundaries, and the role of the asset owner emphasizes contracting, supervision and asset strategy, i.e. strategic management instead of operational management. This evolution highlights the need to better understand the dynamics of service providing networks, or *value nets* (Kleijnen and Smits 2003). The evolution towards dis-integrated organization and network management implies that we can no longer take governance for granted. In the next section we discuss the implications of governance for asset management.

3. ASSET GOVERNANCE

Asset management can be applied in many fields and have a vast interpretation. Each asset management concept and application (within different fields) shares the common theme of strategic importance, systematic processes, optimising efficiency, maximising performance and output, and minimising risks. However, as pointed out by Woodhouse (2006), asset management research and implementation has so far concentrated on the execution of activities that are considered to be asset management, without much thought or insight on the policy and governance structures that define, regulate, and control the execution of such activities. Therefore governance issues which detail the underlying structure of how assets should be managed from a business or management point of view have so far received limited attention.

As mentioned in section 2 asset management research originated from the maintenance of physical assets. However research in this area is limited to certain industries, such as water (Kitchen 2006; Matichich, Allen and Allen 2006; Mergelas 2005) and electricity providers (Cornish and Morton 2001b). Therefore the findings of these research projects were tailored to particular industries, leading to limited generalisability. Industry practitioners have advocated for asset management standards applicable to any organisation where physical assets are a critical factor in achieving effective service delivery. This has lead to the publication of the Publicly Available Specification for Asset Management (PAS 55) by the British Standards Institution (Farrell and Davies 2005; TWPL 2007; Woodhouse 2004). PAS 55 is relevant to managers of asset fleets and contains relevant metrics. In North America, a similar initiative is the publication of the Roadmap for Fleet Managers published by the National Association of Fleet Administration (Golubski 2002). Other national standards have also been published, but so far no universally accepted standard reflecting world best practice has been agreed upon.

This absence of universal standards is arguably due in part to insufficient knowledge about asset governance. As argued in section 2, the evolution of organisational forms requires to reconsider some assumptions that we used to take for granted. The vertical dis-integration of organisations (Hagel and Singer 1999) is leading managers and academics to rethink how the management and governance of assets is conceptualised. The recent emergence of research focusing on asset governance (Cornish and Morton 2001b) provides some initial ideas to begin this process.

Asset governance can be defined as a contemporary way to view the ownership and management of distributed systems in a competitive and deregulated market (Cornish and Morton, 2001). By advocating an asset management practice that is more transparent and accountable, asset governance outlines ways in which assets can effectively be managed in distributed networks in a context where the development, stewardship and operation of assets may be open to competition (Kitchen 2006). Therefore asset governance principles are hihgly relevant to the management of asset fleets. Clear definition and differentiation of roles and responsibilities of the asset owner, asset governor, and the service providers for operational and maintenance activities is central to asset governance (Cornish and Morton 2001b). Asset governance thus provides a framework to manage the separation of powers in asset management that characterises the management of networks (Moore 1993), enabling effective asset management distributed assets.

The application of asset governance principles is outlined theoretically in the UK's Publicly Available Specification for Asset Management (PAS 55) developed by the British Standards Institution (TWPL 2007; Woodhouse 2004; Woodhouse

2006b), and implemented by organisations in the electricity industry (Cornish and Morton 2001b; Farrell and Davies 2005; Kitchen 2006) and gas distribution industry (Woodhouse 2006b). It is recognised that similar opportunities exists in other capital intensive industries, such as infrastructure, railroads and airports (Cornish and Morton 2001b).

The PAS 55 emerged in 2002 to clarify and define a standardised meaning for physical asset management systems. At the time, many managers felt the need to construct a unified view of physical asset management and what it entails. The PAS 55 defines physical asset management as a system that requires a life-cycle view and optimal mix of capital investments, operations, maintenance, resourcing, risks, performance, and sustainability. PAS 55 has been recommended to industry regulators as a framework to audit governance (Woodhouse 2006b). Key asset governance principles embodied within PAS 55 include regulatory compliance, supply business satisfaction, risk-based, data supported, continuous improvement, pragmatic, and income maximisation and generation (Cornish and Morton 2001b; Woodhouse 2004).

Asset governance is still an emergent concept, and its introduction and application within organisations is at an early stage (Cornish and Morton 2001b; Woodhouse 2006b) (Guggenheim and Stahr 2006). Therefore there is a need to explore asset governance in greater depth; investigating possible integrations between asset management aspects and governance structures, applicability within an organisation and across different industries of asset intensive organisations, contingency factors that needs to be considered in formulating policies, and implementation plans that are consistent with other related business system standards and will facilitate its alignment or integration (TWPL 2007).

4. COMPARISON BETWEEN ENGINEERING ASSET MANAGEMENT AND ASSET GOVERNANCE

Comparison of engineering asset management and asset governance literatures show certain areas of convergence. One of the main overlap between the two concepts is that both advocate for a system that will maximise the performance or utilisation of an asset while minimising risk factors. Both concepts also stress the importance in strategic planning and integrating asset-related decisions with organisational/business goals, whilst ensuring equal or higher return on investment at the same time. Minimising cost, or total asset life cycle cost, through careful acquisition, maintenance, and disposal policies is also an area in which asset management and asset governance overlaps.

However there is a fundamental difference between the two concepts. Engineering asset management refers to the operations directing of how asset are managed – how they are acquired, maintained, and disposed in order to maximise operational performance. Asset governance on the other hand concentrates on the reasoning for a particular policy, transparency and accountability in writing and implementing of the policy, and intervention strategies to ensure effective implementation of the policy. Therefore the main link between asset management and asset governance is that asset governance provides the policy structure which determines the space for asset management implementation. Comparing the literature on both asset management and asset governance reveals eight dimensions where the two approaches differ (Table 2). These eight dimensions show the difference between the two approaches and suggest that conflating Engineering Asset Management and Asset Governance would be miguided and lead to failures in decision- and policy-making.

Table 2

A comparison between Engineering Asset Management and Asset Governance Source (Mardiasmo et al. 2008)

	Engineering Asset Management	Asset Governance
Focus	Engineering/Mechanical/ Operational	Policy structuring, decision making process, align operations and business goals
Compliance	Technical specifications, health & safety standards	Industry regulations/rules, international standards, benchmarks
Separation of Power	Asset Manager – day to day operational matters	Asset Governor – long term strategic corporate goals
Time Frame	Long term – whole life cycle	Short term – annual reporting
Application	Operational or divisional level	Corporate core level
Competitive process/edge	Cutting edge specifications. Proactive maintenance and operational risk management	Business level strategies: procurement processes & proactive risk management

Implementation	Technical and business capabilities	Organisational change, local management personalities, organisational structure
Planning Focus	Operational and maintenance planning	Corporate goals, decision making process

As evidenced in Table 2 there are differences in focus between engineering asset management and asset governance. Engineering asset management principles tend to focus on the engineering and operational aspects of an asset's life cycle. In terms of physical assets this focus suggests an asset management regime that is highly concentrated on writing technical specifications, acquiring the asset based on technical specifications, technical maintenance to ensure maximum performance of the asset, and a disposal system that will ensure equal or high return of investment. Asset governance on the other hand concentrates on the processes of rules and regulations development, ensuring the alignment of asset operations to business goals/strategies. Asset governance emphasise the how and why asset-related policies are developed, especially in ensuring policies are developed in alignment with organisational strategy and goals. Asset governance is also focused on how the organisational structure can support effective asset management practices, especially by creating a more streamlined decision making process and clearer lines of responsibility for the asset.

In line with the difference in focus between asset management and asset governance, there is a difference in the standards that each approach adheres to and are evaluated against. Due to its engineering/operational focus, engineering asset management refers to the compliance against technical specifications, health and safety standards, and other operational industry standard. Such a compliance evaluation is executed to ensure that the physical assets acquired are fit for use and will ensure high level operational performance. Asset governance on the other hand ensure the organisation is in compliance with business related industry regulations and rules, and international standards. An explicit example of the difference between the two perspectives is that while asset management concentrates on whether or not a physical asset fulfils technical specifications, asset governance ensures reporting of the physical asset is executed in a standardised manner across the organisation and is available upon request for audit.

One of the main differences between engineering asset management and asset governance according to Cornish and Morton (2001) is the separation of power between an asset manager and an asset governor. The asset manager is primarily concerned with developing the network in line with any contractual conditions and their impact on any risk/rewards mechanisms. This person is responsible for understanding business costs and performance drivers, determining investments to optimise performance and operational costs, managing the delivery of network performance, managing the delivery of investment programmes, monitoring asset conditions, and devising appropriate maintenance policies. Hence the asset manager needs to be able to balance medium term strategy and the day to day performance management. One of the difficulties in a traditional organisational structure is balancing asset managers' demands with those of reducing day to day operational costs. In establishing as asset management service provided and an informed client, the latter is in a position to consider the longer term governance of the assets in more detail and to take a more strategic overview. This leads to the role of an asset governor, who takes a more long term strategic view of the assets and assesses their impact on commercial, statutory, and regulatory requirements. An asset governor provides a skill set that comprises of understanding the lifetime performance and ownership costs of physical assets, understanding the business risk model and the balance between investment and performance, determining a high level overall investment strategy to create and release value, understanding the position of the business in relation to performance and efficiency frontiers, manage competitive procurement process, and identify other opportunities to generate value from the use of assets. Therefore an asset governor's main goal is regulatory compliance, supply business satisfaction, and income maximisation and generation. If we refer to Figure 1 section 2, then we can see that whilst the asset manager from an engineering perspective is concerned with the light arrows, the asset governor's role is focused on the dark ones.

The above description of asset manager and asset governor roles suggests that the management of assets from an engineering perspective may conflict with the governance view. One of the key differences between the two roles, which also lead us to the next difference between asset management and asset governance, is the time frame focus in which strategies are developed. The asset manager is more concerned about day to day operational matters and medium term strategies, whereas the asset governor's planning horizon is more long term. As well as a difference in the time frame of planning, there is also a difference in the planning focus. Cornish and Morton (2001) recognise a main challenge in separating the two functions, namely confusion in the line of responsibility and authority. It is possible for asset users and other asset related employees to be uncertain of whom they should report to.

The description of asset manager and asset governor above, along with their difference in time frame of planning, leads to the difference in the scope of application between asset management and asset governance. Engineering asset management has a greater focus on operational matters: as asset managers have a day to day operational and medium term planning time frame, their focus is primarily towards the engineering operation of the assets. Asset governors meanwhile have a planning focus that is concentrated at ensuring that asset management operates within an appropriate governance context. Hence asset governance has a greater orientation towards corporate policies and strategy, with an emphasis on how assets can be utilised to meet business goals and create value for the organisation.

5. DISCUSSION

How to reconcile the different foci and orientations of engineering asset management and asset governance is a strategic governance issue that senior management and boards should address. Ignoring the need to differentiate between the roles of asset manager and asset governor may lead to overemphasize one role at the expense of the other, and trigger sub-optimal engineering asset performance, or poor asset governance outcomes.

One of the difficulties in resolving the management trade-offs associated with engineering asset management and asset governance is related to the need to take into account multiple measures of performance and multiple objectives. It has been suggested that a tool such as the Balanced Scorecard (BSC) (Kaplan and Norton 2001) could be useful in this endeavour, as the balance scorecard has been conceived with the need to reconcile and align multiple objectives at all levels of the organisation in mind.

The BSC provides a framework for studying dependencies between KPIs reflecting four perspectives (or dimensions) as shown in Fig. 6 (Kaplan & Norton 2001):

Financial: typically relates to profitability – measured by ROI, ROCE and EVA, for instance;

Customer: includes several generic measures of the successful outcomes of company strategies - for instance, customer satisfaction, customer retention, and market share in targeted segments;

Internal processes: focuses on the internal processes that will have significant impact on customer satisfaction and on achieving the organisation's financial objectives – classical measure is OEE;

Innovation: identifies the infrastructure the organisation sustains and develops in order to create long-term growth and improvement through technology, skills and organisational procedures.

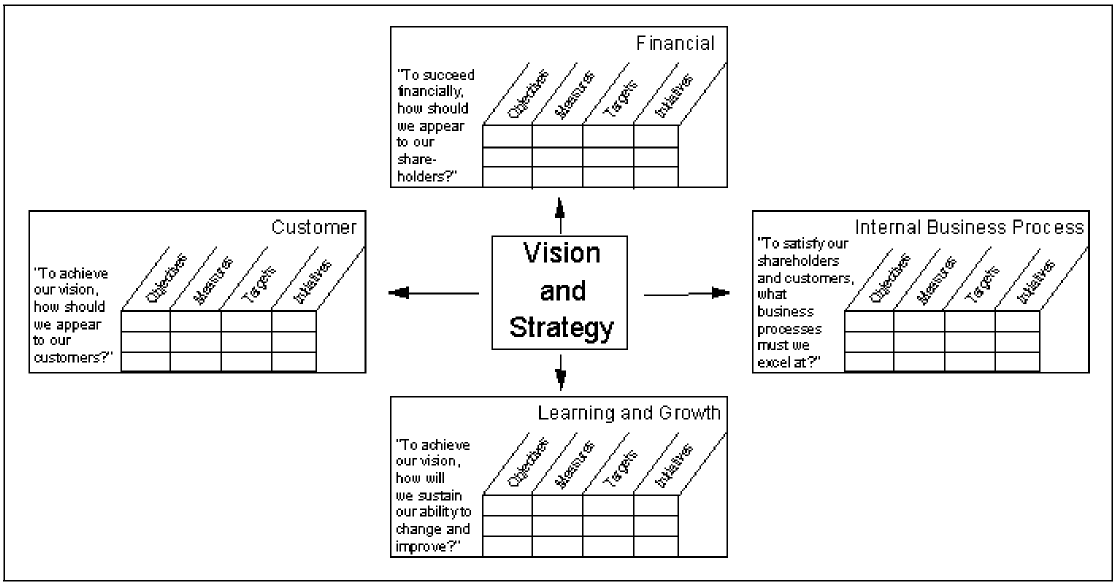

Figure. 6. Balanced Scorecard: the four original dimensions - each specified in terms of objectives, measures, targets and initiatives (Kaplan & Norton 2001).

Considering today's demand on efficiency and effectiveness competition is harder on all the basic dimensions. In a buyer's market it is obvious that customer objectives will be crucial (remembering that in a supply chain or supply network, one company's customer may be another company's supplier). The internal process objectives are key for meeting increasing competition in a deregulated market. Thus product and process innovations are important for staying in the business in the long run. Good performance in the above dimensions will obviously correlate positively with good financial performance.

By enabling to translate broad corporate strategic objective across a range of dimensions, the BSC provides a framework to identify potential conflicts and trade-offs between asset governance and engineering asset management. However, it is not sufficient to guarantee success on its own. Appropriate governance structure must be in place so that trade-offs are identified in a timely fashion, and reporting and accountability policies and processes must be architected in a way that incentivises managers to deal appropriately with these challenges, and conflict resolution and consultation forums must be in place to enable asset managers and asset governors to work in good intelligence.

One of the challenges for senior management in tackling this issue is to avoid over-governance and the bureaucratisation of the organisation (Gulati and Kletter 2005). Rather, the judicious application of well-designed simple rules has been suggested to be more effective (Eisenhardt and Sull 2001). Research in organizational design suggests that contingency models need to be continuously adapted to the changing needs of organisations in the context of rapidly changing environments (Miller 2005). This opens up the need to address research questions relating to the appropriate rules and contingencies for governance architectures that support high performance asset engineering management and asset governance.

6. FUTURE RESEARCH

We will conclude the paper with some remarks related to the special challenges of integrating the engineering and the governance perspectives for the asset management of fleets, and the needs for future research to meet these challenges. From the point of view of engineering asset management the key challenges is to define key performance indicators, operationalise their measurement, and evaluate the performance of the individual entities, as well as, the fleet as a whole. From the point of view of asset governance the key challenges are the definition of rules to by which a networked organisation comprising of an asset owner, asset user and service providers is constructed: What the roles, accountabilities, IPRs, required capabilities of the different actors in the network? How do we evaluate the added value of the network? More particularly, how do we define gains and responsibilities among the actors for a joint gains situation? What business models could provide this joint gains situation? What incentive models should be built in? These questions are implicit in Fig. 7 that sketches information flows between the fleet owner, fleet user and the network of service providers.

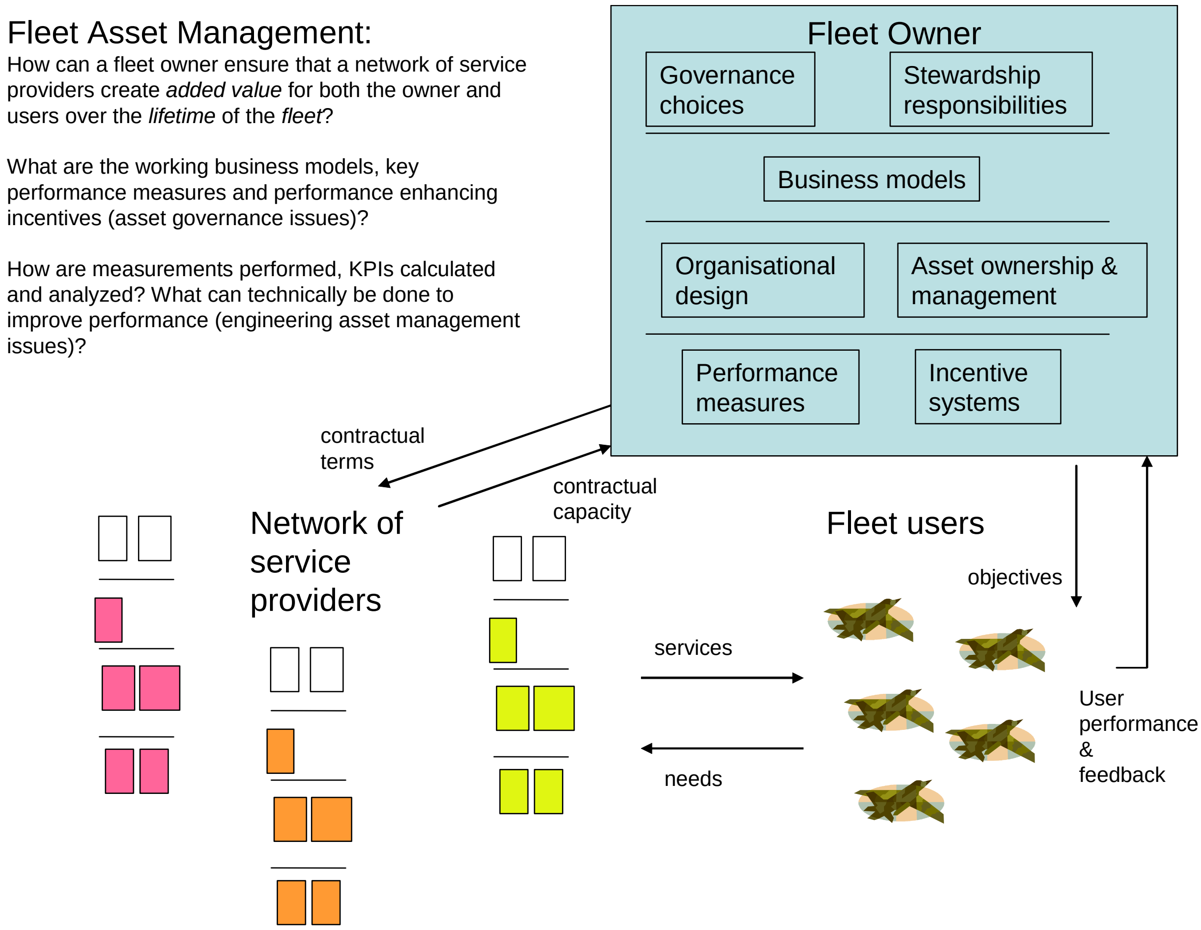

Figure 7. Networked fleet asset management

Future research is required to better understand the relationship between the stakeholders to be able to improve asset management and governance of asset fleets. Integration of the engineering and governance perspectives is believed to be a step forward. Ideally, the results of future research should support stakeholders in identifying their success factors and in the formulation of service and business models that jointly yield a win-win situation for the all the network members.

7. References

Alchian, A. A. and H. Demsetz. 1972. Production, Information Costs, and Economic Organisation. *American Economic Review*, 62: 777-795.

Alles, M. G., S. M. Datar and J. H. Friedland. 2005. Governance-linked D&O Coverage: Leveraging the Audit Committee to Manage Governance Risk. *International Journal of Disclosure and Governance*, 2 (2): 114-129 (accessed June 2005).

Andreou, A. N. and N. Bontis. 2007. A Model for Resource Allocation Using Operational Knowledge Assets. *The Learning Organization*, 14 (4): 345.

Barney, J. B. and W. Hesterly. 2006. Organisational Economics: Understanding the Relationship between Organisations and Economic Analysis. In *The SAGE Handbook of Organisation Studies*, Vol. 2nd ed, eds. S. R. Clegg, C. Hardy, T. B. Lawrence and W. R. Nord. London: SAGE Publications Ltd.

Bhagwat, R. and M. K. Sharma. 2007. Performance Measurement of Supply Chain Management: A Balanced Scorecard Approach. *Comp. & Ind. Eng*, 53: 43-62.

Bühner, R. 2000. Governance Costs, Determinants, and Size of Corporate Headquarters *Schmalenbach Business Review : ZFBF*, 52 (2): 160.

Chen, L. and S. Mohamed. 2007. Empirical Study of Interactions Between Knowledge Management Activities. *Engineering, Construction and Architectural Management*, 18 (1): 107-116.

Considine, M. and J. M. Lewis. 2003. Bureaucracy, network, or enterprise? Comparing models of governance in Australia, Britain, the Netherlands, and New Zealand. *Public Administration Review*, 63 (2): 131.

Cornish, N. and K. Morton. 2001a. Asset Governance - A radical new way to manage distribution networks in a competitive and deregulated market. *London Electricity's Distribution Business*, 482 (June): 18-21.

Cornish, N. and K. Morton. 2001b. Asset Governance - A Radically New Way to Manage Distribution Networks in a Competitive and Deregulated Market. In *16th International Conference and Exhibition on Electricity Distribution (CIRED 2001)*. Amsterdam, Netherlands: Institute of Electrical and Electronics Engineers.

Davis, J. 2007. What is asset management and where do you start? *American Water Works Association. Journal*, 99 (10): 26.

Dunis, C. and J. Miao. 2006. Volatility filters for asset management: An application to managed futures. *Journal of Asset Management*, 7 (3/4): 179.

Eisenhardt, K. M. and D. N. Sull. 2001. Strategy as Simple Rules. *Harvard Business Review*, 79 (1).

Fabrycky, W. and B. Blanchard. 1991. *Life-Cycle Cost and Economic Analysis*. Englewood Cliffs, NJ: Prentice Hall.

Farrell, L. and R. Davies. 2005. *National Grid officially recognised by Lloyd's Register for Asset Management* National Grid.

George, W., F. W. McFarlan and I. Marco. 2006. Organization Design and Effectiveness over the Innovation Life Cycle. *Organization Science*, 17 (2): 230.

Golubski, P. 2002. A Roadmap for Fleet Managers. *Fleet Equipment*, 28 (11): 10.

Gomez, P.-Y. 2004. La gouvernance de l'entreprise. *Revue Française de Gestion*, 30 (148): 249.

Guggenheim, R. and R. W. Stahr. 2006. Asset Management Program Implementation: What a long, strange trip it's been. *American Water Works Association. Journal*, 98 (1): 34.

Gulati, R. and D. Kletter. 2005. Shrinking Core, Expanding Periphery: The Relational Architecture of High Performing Organisations. *California Management Review*, 47 (3): 77-104.

Hagel, J. and M. Singer. 1999. Unbundling the Corporation. *Harvard Business Review*, 77 (2): 133-141.

Herder, P. M. and Z. Verwater-Lukszo. 2006. Towards Next Generation Infrastructures: An Introduction to the Contributions in this Issue. *International Journal of Critical Infrastructures*, 2 (2/3): 113-120.

Jabiri, N. Z., A. Jaafari, R. Platfoot and D. Gunaratram. 2005. Promoting Asset Management Policies by Considering OEE in Products' TLCC Estimation. In *Engineering Management Conference Proceedings*: IEEE International.

Jensen, M. C. and W. H. Meckling. 1976. Theory of the Firm: Managerial Behaviour, Agency Costs, and Ownership Structure. *Journal of Financial Economics*, 3: 305-360.

Kaplan, R. S. and D. P. Norton. 2001. *The Strategy-Focused Organisation: How Balanced Scorecard Companies Thrive in the New Business Environment*. Boston, Massachusetts: Harvard Business School Press.

Kim, Y.-M., J. Ahronheim, K. Suzuka and L. E. King. 2007. Enterprise Digital Asset Management System Pilot: Lessons Learned. *Information Technology and Libraries.*, 26 (4): 4-16.

Kitchen, H. 2006. A State of Disrepair: How to Fix the Financing of Municipal Infrastructure in Canada. *Commentary - C.D. Howe Institute* (241): 0_1.

Kleijnen, J. P. C. and M. T. Smits. 2003. Performance Metrics in Supply Chain Management. *Journal of the Operational Research Society*, 54 (5): 1-8.

Komonen, K., H. Kortelainen and M. Räikkönen. 2006. An Asset Management Framework to Improve Longer Term Returns on Investments in The Capital Intensive Industries. In *WCEAN*. Queensland, Australia.

Lin, S., J. Gao, A. Koronios and V. Chanana. 2007. Developing a Data Quality Framework for Asset Management in Engineering Organisations. *International Journal of Information Quality*, 1 (1): 100-126.

Mardiasmo, D., S. Tywoniak, K. Brown and K. Burgess. 2008. Asset Management and Governance: Analysing Vehicle Fleets in Asset-Intensive Organisations. In *The Twelfth Annual Conference of the International Research Society for Public Management (IRSPM XII)* Brisbane, Australia.

Matichich, M., J. Allen and R. Allen. 2006. Asset Management Planning and Reporting Options for Water Utilities. *American Water Works Association. Journal*, 98 (1): 80.

Mergelas, B. J. 2005. Condition-based asset management strengthens bottom line. *American Water Works Association. Journal*, 97 (2): 48.

Miller, D. 2005. Advantage by Design: Competing with Opportunity-based Organizations. *Business Horizons*, 48 (5): 393.

Mitchell, J. S. 2002. *Physical Asset Management Handbook*. 3 ed: Clarion Technical Publishers.

Mitchell, J. S. and J. Carlson. 2001. Equipment asset management – what are the real requirements? *Reliability Magazine*, 4 (14).

Moore, J. F. 1993. Predators and Prey: A New Ecology of Competition. *Harvard Business Review*, 71 (3): 75-83.

Moore, M. H. 1995. *Creating Public Value Strategic Management in Government*: Harvard University Press.

Narracott, M. and A. Bristow. 2001. Corporate governance in Australia. *International Financial Law Review*: 35.

Rosqvist, T., K. Laakso, and M. Reunanen, M. 2007. Value-driven maintenance planning for a production plant. *Reliability Engineering & System Safety*. In press. Available

online at www.sciencedirect.com.

Schmidt, S. L. and M. Brauer. 2006. Strategic Governance: how to assess board effectiveness in guiding strategy execution. *Corporate Governance: An International Review*, 14 (1): 13-22. http://www.blackwell-synergy.com/doi/abs/10.1111/j.1467-8683.2006.00480.x.

SEMI. 2000. Standard for Definition and Measurement of Equipment Productivity. In *SEMI E79-0200*: Semiconductor Equipment and Materials International, Mountain View, CA.

Sturgeon, T. 2002. Modular Production Networks: A New American Model of Industrial Organisation. *Industrial and Corporate Change*, 11 (3): 451-96.

TWPL. 2007. *PAS 55 - what makes TWPL different?* The Woodhouse Partnership Limited. http://pas55.net/ (accessed 28 November, 2007).

Wenzler, I. 2005. Development of an asset management strategy for a network utility company: Lessons from a dynamic business simulation approach. *Simulation Gaming*, 36 (1): 75-90. http://sag.sagepub.com/cgi/content/abstract/36/1/75.

Wittwer, E., J. Bittner and A. Switzer. 2002. The fourth national transportation asset management workshop. *International Journal of Transport Management* (1(2)): 87-88.

Woodhouse, J. 2004. *PAS 55: Specification for the Optimized Management of Physical Infrastructure Assets*. The Institute of Asset Management. http://www.iam-uk.org/downloads/PASworkshop.pdf (accessed 28 November, 2007).

Woodhouse, J. 2006a. Putting the total jigsaw puzzle together: PAS 55 standard for the integrated, optimized management of assets: The Woodhouse Partnership Ltd, Institute of Asset Management.

Woodhouse, J. 2006b. Putting the Total Jigsaw Puzzle Together: PAS 55 Standard for the Integrated, Optimized Management of Assets In *International Maintenance Conference*. Daytona Beach, Florida.